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UNIVERSITY OF MISSOURI

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WHAT SHOULD A PRESENT DAY METALLURGICAL EDUCATION COMPRISE?

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An Address By

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Professor of Metallurgy, Case School of Applied Science

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WHAT SHOULD A PRESENT DAY METALLURGICAL EDUCATION COMPRISE?

CHARLES HERMAN FULTON, D. Sc.

Annual Commencement Address, May 25, 1917

During the last decade the production of metals in the United States has greatly increased, and an intensive spirit has taken hold of the metallurgical industry, which is being reflected in metallurgical education.

In order to clearly view present day tendencies we should look at the origin and early methods of metallurgical education in this country. Naturally the bond between an industry and the teaching of its art is very close, so that the growth of an industry implies a growth in the teaching of its art. Except for iron, the extent of metallurgical industry in this country previous to 1860 was small, particularly when it be compared to its present magnitude. With the discovery of the great western ore deposits and the production of metals from these sources, a decided need began to be felt for men who had a knowledge of metallurgical processes, or a knowledge of the fundamental scientific principles which were involved in their practice. That men of this kind were few in number in the United States becomes at once apparent when the nativity of the early metallurgical pioneers is considered. They all came to us from abroad, as, for instance, Anton Eilers, O. H. Hahn, August Raht, Chas. A. Stedefelt, Richard Pearce, and others, all of them men who had received their education and had acquired their knowledge either in Germany or in England. In those days there would have been no response to an advertisement in the technical mining press, if there was one, for a young American trained in mining and metallurgy. It was the urgent need of such men by the young and growing industry that led to the establishment of the pioneer courses in mining

and metallurgy in Columbia College in New York and in the Massachusetts Institute of Technology in Boston. In those early days there was but little distinction made between mining and metallurgy. The two went hand in hand, and such a thing as a course in metallurgy as distinct from mining was not considered. The formulation of the course of study was well and wisely done by such men as R. H. Richards, C. F. Chandler, Thos. Eggleston, J. S. Newberry, F. L. Vinton, and others, and was based largely on the work of the School of Mines at Freiberg in Saxony and that of the Ecole des Mines at Paris, as well as on the practical demands of the young American industry. The course included the teaching of a fundamental knowledge of mathematics, chemistry and physics, which were considered essential. This was amplified by special knowledge in chemistry relating to the recovery of the common metals, iron, copper, lead, zinc, gold and silver. Further, it included a knowledge of general geology and of ore deposits, although this last subject was in its very infancy, of surveying land and mines, of the principles of steam and water power, and power application, in a relatively rudimentary way, as well as a knowledge of engineering structures. All of these subjects were taught distinctly in a descriptive way, and laboratory instruction was comparatively limited even in physics and chemistry, although the great importance of it was fully recognized. Books dealing with special subjects of metallurgy and mining were not numerous, and those used were almost entirely French, German and English. There were practically no American text books available at that time.

This early education in mining and metallurgy reflected the condition of the industry at that time just as the more modern education in these subjects reflects its present condition.

During the period from this beginning to the present there occurred a general expansion of the course of study as the needs of the industry grew. The number of the subjects taught and their complexity increased. The growth may be classified in three groups:

1. There was an increase in the amount of laboratory work in chemistry and in physics, and laboratory or field work was introduced in surveying, in metallurgy and ore dressing, in geology, in drafting and design, in electricity, hydraulics, and in power engineering.

2. As the industry expanded **new** subjects were introduced, and older subjects grew in complexity, as, for instance, electricity, at first taught as a purely physical sub-

ject, was gradually transformed into an engineering subject, and now takes on the importance in the one case of a special branch of metallurgy and in the other of a great and important branch of power engineering. In the production of power the early field was limited and descriptive methods only were employed. Power was produced by relatively simple machinery—ordinary boilers, the slide valve steam engine, and water wheels. Simple jaw crushers, rolls, stamps, jigs, screens and pans comprised the milling machinery. Now the subject of power engineering has much broadened and is complex, including the intricate boiler plant, modern steam engines and turbines, gas producer power plants, gas engines, generation of electrical energy, its transmission, and manifold detailed application to mining and metallurgical work, while milling and smelting machinery is almost endless in its variety.

3. The literature of the art in the earlier days was limited and comparatively simple. The time required to become acquainted with its essential features was short. Now this literature has swollen into a great stream and it requires much time to become familiar with the essentials only.

During this period of growth the mining and metallurgical courses have drifted apart and become distinct in most educational institutions. In this respect education has followed the practice of the industry, for while formerly the mine and its metallurgical plant were closely related, this is not true at the present time, except in isolated instances.

The very close relation between technical education and industry has already been stated, but in view of the importance of the fact may again be emphasized: it is the function of technical education to prepare men for useful work in industry. It seeks to train them within a comparatively narrow and confined field to do certain highly useful things. In this respect technical education differs greatly from the general or cultural education. This latter has the fuction of broadly training the mind, establishing and fixing character, but not of preparing for a special life work. Technical education always has a specific and narrow object in view. Both types have their place and value, but they will not mix well in the same course. There is frequently criticism of educational institutions by men in industrial leadership, and in the very nature of things they have a right to criticise technical schools, since their criticism is directed towards something which is really part of the industry they represent. Whether their criticisms are always just

is another matter. In many instances undoubtedly it is. There can be no question, however, of their right to criticise and suggest in a matter in which they are vitally concerned, since they take the product of the technical school and use it. It is conceded that the director of a metallurgical works has the right to express what he believes should be the training and qualifications of a man coming to him to do certain useful work.

Our schools which teach mining and metallurgy are of three kinds:

1. The university, of which the School of Mines is a part.
2. Technical schools which include in their curriculum a number of courses in technology, including mining and metallurgy.
3. Schools of mining and metallurgy, which confine themselves to these courses.

The course of study taught in institutions is based on precedent, representing the past needs of the industry, and on the ideas and suggestions of the men who make up the faculties. The three classes of institutions have different types of faculties. While in the university the faculty as a whole does not make the course of study of any particular school in the university, nevertheless the influence of the whole faculty is felt in the course of study, unless the university be a very large one. In a school of technology teaching all technical courses the faculty comprises less diversified elements than in the university and its views are more confined. In the school of mines the faculty is quite limited and the fields of knowledge represented are relatively few.

In the university there will be a tendency to broaden the course of the technical student. In the school of mines and metallurgy there will be a tendency to narrow and confine the course of the student. The school of general technology will stand between the two in this respect. The question now arises as to what is best for the student. Is it the so-called broader education, or is it the relatively narrow education?

The marked tendency in most institutions is to "broaden" the education. For instance, the department of English discovers that the student is lacking in facility in using the language; the department of modern languages finds that the student is deficient in German and French; it believes also that in view of developments in South America he should be taught Spanish in order to make him more useful; the department of mathematics would like to "broaden" his outlook by the addition of some newly discovered

methods of solving equations; the department of history thinks that a little more history would tend to "broaden" him and assist in forming his character. Every one is much interested about his being properly "broadened" in the cultural subjects. The technical men on the faculty, however, become somewhat concerned as to whether this "broadening" process may not, in reality, be a "narrowing" process, since it strikes at the student's real work in life, which he is supposed to be fitted for by the institution he is attending.

It seems evident in view of the number of professional subjects that are, in this modern day, required of the mining and metallurgical engineer, that any considerable time of the course which is taken away from professional subjects will "narrow" him decidedly in matters he should know most about, and which he is expected to know and make a creditable showing in upon entering practical life.

The English department, the modern language department and the other departments spoken of are right in their view that a man should be broadened in these subjects. The better the training and the more education of a general character that a man has, the better and more useful citizen he will make, but it must always be remembered that the ultimate and final object for which he attends a technical school and seeks a technical education is to obtain specific knowledge of certain subjects which will enable him to be useful in this particular work after his graduation. He should attain this condition of usefulness shortly after leaving school, and not only at the age of seventy, when he is ready to graduate from life's school.

The essentials of the matter may be summed up in this statement: The student should have acquired a general education when he enters the technical school, and should not acquire it during his residence there as part of the regular curriculum. Perhaps the real difficulty in the matter is to be found in the primary and secondary educations which he receives. The total length of time of this preparatory education is twelve years, eight in the primary school and four in the high school. If to this be added one year or two of general college training, or if the high school course be made five years, he should have acquired sufficient general education to enable him to broaden himself if that be necessary, and not take time from that allotted to his specific technical education to do so.

As the present courses in the preparatory school are arranged, it is difficult for the man to obtain this general education. With the introduction of vocational training, the

student is taught a little of each of many subjects, and not much of any one subject. This type of education no doubt fulfills a useful function to the man who is to stop with the high school, but for the one who is to take up technical work it is much better to confine him to a rigorous and extensive training in English, one foreign language and its literature, elementary chemistry and physics, very thoroughly taught, mathematics, including trigonometry, and thorough courses in history, and geography. There is time enough to thoroughly teach these subjects. At the present time when the technical school wishes to broaden him, what it really means is that it desires to correct the defects of his secondary education. In reality it does not add anything new, but goes over old ground which has been imperfectly covered, and corrects work which has been poorly done.

It appears that the sooner these fundamental conditions are recognized in technical education the more rapid the progress will be. As to the past methods and the future tendency of mining and metallurgical education, it is of interest to consider two of the foremost institutions in this country.

The School of Mines of Columbia College, as it was formerly known, has always followed the policy that the time of the course should be devoted solely to technical training. This was never understood to mean that the education should be narrow, for the requirements for entrance were such that the student had a good general education upon taking up his technical work. In the new system now adopted at Columbia University this fundamental idea has not been abandoned, but rather extended. The requirements for preparation for technical work are increased, so that the student is not in need of being "broadened" during the time of his technical training, but, on the contrary, can give most strict attention to his real work, which, to meet modern conditions, has been amplified and enlarged.

As I understand it, the ideals and policy governing the course at the Massachusetts Institute of Technology before its identification with Harvard University were of a different character, the course including a number of non-technical subjects not relating strictly to mining and metallurgical work, and tending to afford a more general education to the technical student. The institute course taken as a whole was less strictly technical than that at Columbia. I have met many graduates of both institutions, and it is difficult to discern any difference in qualifications and ability of the

graduates, for both schools have always insisted on close and intensive technical training.

Many of the mining schools, in order to open the door of opportunity for an education to as many as possible, have never adopted high entrance standards, or have not raised their original standards, with the result that their courses contain subjects which decrease very much the efficiency of the technical education offered. That is, they are doing part of the preparatory work. The time has come when these institutions must take a position on one side of a line or the other. They will become either institutions that train engineers in the full sense of the word, or they will become institutions whose function it is to furnish a technical education of the trade type. They will become mining or metallurgical trade schools. I am by no means drawing invidious comparisons between the two types of schools, for in the American system of education we need both types, and the last fulfills an equally important function with the first. The point at issue is that a school cannot very well combine both types of education into one.

In proceeding to outline what is the best course of study for the metallurgical engineer I refer only to the engineering school, and not to the metallurgical trade school. It is assumed that the entering student has received a thorough preliminary training of the nature discussed. The course will then be as follows:

1. Mathematics—This will consist of analytical geometry, advanced algebra and differential and integral calculus. These subjects are to be taught thoroughly with the working of many problems, so that mathematics will become a really efficient tool in the hands of the student. How this is to be done is left entirely to the department of mathematics. The student should have the ability to use calculus as readily as he does arithmetic. The pure mathematics are followed by theoretic mechanics. The principles of mechanics should so become a part of the student's mind that he can automatically detect the perpetual motion phantasy, no matter in what guise it is presented to him. He should be so trained in mathematics and mechanics that it will be possible for him to see in the abstract, and there will be no need for every problem to be made concrete.

2. Physics—The student comes to the technical school with a thorough knowledge of general physics. He is familiar with the principles of light, heat, electricity, sound and mechanics. The technical course in physics therefore

should be directed to an extensive study and training in heat, electricity and such other physical phenomena as particularly apply to metallurgy, as for example, viscosity, surface tension, adsorption and other molecular forces. He should obtain not only a general knowledge, but a detailed knowledge, and be able to apply this later on to problems of a metallurgical character. Laboratory work in connection with this subject should include a thorough technical study of pyrometry, heat measurements of all kinds, and electrical measurements in both direct and alternating currents, and in magnetism.

3. Chemistry—This course should be begun with the study of general theoretic chemistry and physical chemistry, the individual subjects being carefully chosen, so as to bear particularly on metallurgy. The subjects of solution, electro-chemistry, equilibrium reactions, etc., should be thoroughly mastered. Then will follow a course in analytical chemistry with particular reference to metals. It is not the idea to train an analytical chemist, but rather to give a thorough insight into methods. In our present courses too much stress is laid on analytical chemistry. The final course in chemistry should be one in industrial chemistry, so as to give the student a broad outlook into the manufacturing principles and methods of such common substances as the alkalies, sulfuric, hydrochloric and nitric acid, chlorine, nitrogen, oxygen, byproduct coke, etc., all of which have a bearing on metallurgical work.

4. Drafting—Design of structures and materials of engineering are included in this course. The student is supposed to come thoroughly trained in freehand drawing and simple mechanical drafting. The drafting work should therefore be combined with the theoretical study of engineering structures in their simpler form and the properties of the materials of engineering. It is not intended that subjects of a mechanical engineering nature be here included, but the work is of a civil engineering character.

5. Mechanical Engineering—This should include a thorough course in power plants, the generation of power by different methods, steam, electricity, gas engines, compressed air, and hydraulic methods. The student must become thoroughly familiar with the production and application of power and the economics of the subject. In this department should be taught in detail the subject of the moving and handling of material by means of cranes, hoists, mechanical unloaders, conveyors, elevators and kindred apparatus. He should be taught the methods of producing

pressure air by means of compressors, blowers, turbine blowers, fans, etc. The course will include the subjects of rolling mills, forging machines, hammers, crushing machinery, and other mechanical appliances employed in metallurgy. Some of these are now included in other courses, but they are so purely of a mechanical nature that they are best grouped under this head.

6. Electrical Engineering—This subject includes a thorough training in the principles and application of direct and alternating currents. It should not include design of electrical machinery. It should cover the construction and electrical operation of electric furnaces and the electrical design and construction of electrolytic plants from the standpoint of the metallurgist. It should include the operation of plants, power transmission and the use of commercial electrical instruments. Many metallurgical engineers are deficient in a knowledge of electrical engineering, at present a very vital subject. In this work it is the object to give the student a thorough knowledge of electricity as applied to metallurgy, but not to make an electrical engineer of him.

7. Mineralogy and Geology—The course in mineralogy should be very thorough, particularly in determinative mineralogy. Crystallography need not be emphasized, but so much given as is necessary. The course in general and economic geology need not be extensive, as would be the case in training mining engineers, but considerable work should be given in petrography, or rather in optical mineralogy, so that the student will be proficient in the use of the microscope, and can use it later in metallurgical problems that may arise.

8. Biology—It is desirable that the student should have a good course in general biology, so that he may have knowledge of the relation of mankind to nature. This course may well include a broad view of anthropology and archaeology to give him some idea of the early history of man and his development.

9. Economics—A thorough course on the principles of economics is essential to the student. This course should include especially the subjects of transportation, labor and related questions and social work.

10. Business—Since the production of metals on a large scale may be considered as a purely business operation, the student must have a knowledge of the subject of business. This should include such general topics as banking, tariff, accounting, bonds and stocks, followed by detail-

ed instruction in metallurgical accounting and metallurgical business, including the buying and selling of metallurgical products, the business administration of metallurgical works and all matters of business interest relating to metallurgical plants. In this course lectures should be given by men familiar with practical metallurgical business, to amplify the regular instruction by members of the faculty.

11. Mining—The instruction in mining need not be extensive. There should be a good course in the principles of mining, and the close business relation between mining and metallurgy should be shown.

12. Surveying—The student should have a course in surveying, including ordinary land surveying, the laying out of sites, topographic surveying, mapping and plane table work. The main object of this course is to prepare the student to lay out metallurgical plants.

13. Metallurgy—Metallurgy is the most important single subject for the student. All his other work is taught from the viewpoint that it has a distinct bearing on and connection with metallurgy. The first course in metallurgy will be one in general metallurgy. It serves to give the student a broad view of the underlying principles and methods which govern the recovery of the useful metals on a commercial scale. It includes such matters as are closely related to metallurgy, as fuels, combustion, materials used for metallurgical construction, etc. This will be followed by work in the metallurgy of the common metals. In the descriptive work of these courses it will be desirable to discuss only the most modern practice, and not burden the student with matters that have become history. A course in metallurgical design will follow, covering the principles of metallurgical construction and the application of materials to this construction. The work should be of a detailed rather than of a general character. It should not be an elaborate problem like the design of a smelter or of a concentration plant, but the effort should be directed to the design of a piece of apparatus, say, a reverberatory furnace for smelting calcined flotation concentrate, or a heating furnace for steel billets, or a tank for leaching copper ores. The problem of design should be a perfectly definite one, and the limiting conditions fully stated. Work should also be given relating to general plant layout. In many institutions the method of teaching design is faulty. It is customary to have a student draw, for instance, a stamp mill, a concentrating mill, or a smelting plant, which, when finished, looks attractive

on paper, but is practically nothing more than a composite copy of a number of blue prints which the student used in order to obtain suggestions. The final test of design comes in construction and use. This test of course can rarely be applied to student work, but there is a possibility for some of the design to be in the nature of relatively simple apparatus or appliances, which may later be built and used in the laboratory.

There should be a course in the history of metallurgy to make clear the development and evolution of metallurgical processes. This course need not be extensive, but it will be valuable to the student in relating present day practice to the past. A thorough course in metallography is essential, and should cover the physical properties of metals, and alloys, and their heat treatment, in a scientific way. The subject of alloys is very important, and the student must have specific knowledge on this subject.

14. Laboratories in General—The laboratory work of the course is to be extensive. There should be ample laboratory facilities in physics, chemistry, electrical engineering, mechanical engineering, mineralogy, metallography and metallurgy. The laboratories should be open during the school day, in charge of instructors who devote their time solely to laboratory work, so that a student may ultilize free time when he so desires. This does not imply that there should be no regular laboratory periods in which the standard work is scheduled, but rather that the laboratory opportunities be broadened to enable the student to do additional work, or make up work if it be necessary. As far as possible there should be individual apparatus of high grade. It is undesirable to work with poor instruments.

15. Metallurgical Laboratory—The usual idea of a metallurgical laboratory is a large room or separate building, in which is housed concentrating machinery such as jigs, classifiers, screens, crushers of various kinds, and other standard metallurgical apparatus, as some kind of roasting furnace, blast furnace, cupola, stamp mill and amalgamating plate, etc. This collection is supposed to represent common metallurgical apparatus in use in metallurgical plants of various sorts, and it is expected that the student will operate this apparatus, and thus gain some knowledge of actual methods to amplify his theoretical instruction in the class room. As a matter of fact, many of the metallurgical laboratories are museums of apparatus and their actual use is small.

There is much discussion whether, for the purposes of instruction, full sized metallurgical apparatus is desirable, or whether it is better to use small sized apparatus in the nature of working models. Both systems have their warm adherents, and something may be said on both sides. From a practical standpoint it is difficult for most institutions to operate full sized apparatus, as the cost and time required is too great. If circumstances are such, for instance, that a small blast furnace can be run continuously for a week or ten days by a crew of students in charge of competent foremen, the value of this work to the student will be very great. If, however, an attempt is made to operate it but for a day or so, without adequate preparation, the results are negative and may be harmful. For this reason it is better to keep to the teaching of principles in small sized apparatus, and do this work thoroughly after the manner that has been developed by the Massachusetts Institute of Technology. The actual commercial operation involving these principles can then be studied during practice terms or summer school. Metallurgical laboratories that contain a large collection of full sized apparatus, little of which is ever used, are a useless encumbrance to a mining school.

The most modern conception of a laboratory is a large fire-proof building, rectangular in shape, of ample height and provided with a 5 to 10 ton crane that runs the length of the building. This room or building contains electrical switch-boards, from which may be taken an ample supply of direct and alternating current, within a wide range of voltage. The building will be provided with high pressure air and water; it will contain standard crushing machinery, such as a gyratory crusher, rolls and a fine crusher of some sort and screens; it will contain a number of different sized motors, which can be used anywhere within the building. The laboratory will be provided with a fully equipped carpenter and machine shop. This constitutes the permanent equipment of the laboratory. All other apparatus will be either built to suit the special purpose required, or purchased as it is needed, but has no permanent place; although later on, if deemed advisable, certain pieces of apparatus may become permanent. In a laboratory of this kind really modern work may be carried on in concentration, roasting, leaching, smelting, electric furnace work, electrolytic work or any metallurgical problem that may arise.

COMMENCEMENT ADDRESSES
1901-1917

1901 The Development of American mining and metallurgy, and the equipments of a training school. James Douglas, LL.D., President, Copper Queen Mine. (Out of print).

1902 Mining and metallurgy in some of their relations to the progress of civilization. William P. Blake, F.G.S., Director, Arizona School of Mines. (Out of print).

1903 Science and practice. Regis Chauvenet, LL.D., Mining Engineer. (Out of print).

1904 The Engineer and his relation to modern methods. Charles J. N. Norwood, M.Sc., Director, Kentucky Geological Survey. (Not published).

1905 Ore treatment in the southeast Missouri lead district. Oscar M. Bilharz, E.M., Chief Engineer, St. Joseph Lead Co. (Not published).

1907 Compound numbers. John Henderson Miller, D.D., Kansas City. (Not published).

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1909 The Relation that exists between general and technical education. A. Ross Hill, LL.D. President of the University. (Not published).

1910 Some of the essentials of success. Charles Sumner Howe, LL.D., President, Case School of Applied Science.

1911 The individual, the state and the nation in the development of our mineral resources. Joseph Austin Holmes, LL.D., Director, U. S. Bureau of Mines. (Not published).

1912 Mining and civilization. James Ralph Finlay, A.B., Consulting Mining Engineer.

1913 Measuring the output. Edwin Earle Sparks, LL.D. President, Pennsylvania State College. (Not published).

1914 The West. Frank Strong, LL.D. Chancellor, University of Kansas. (Not published).

1915 Place and influence of the engineer. Elmer James McCaustland, M.C.E., Dean of the School of Engineering of the University. (Not published).

1916 The Business of mining. Walter Renton Ingalls, S.B. Editor, The Engineering and Mining Journal.

1917 What should a present day metallurgical education comprise? Charles Herman Fulton, D.Sc., Professor of Metallurgy, Case School of Applied Science.

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Vol. 1, No. 2, March, 1909. 38th Annual Catalogue, 1909-1910.
Vol. 1, No. 3, June, 1909. Education for utility and culture. Calvin M. Woodward (Tau Beta Pi address.)
Vol. 1, No. 4, Sept., 1909. The history and the development of the cyanide process. Horace Tharp Mann.
Vol. 2, No. 1, Dec., 1909. The Jackling field, School of Mines and Metallurgy.
Vol. 2, No. 2, 39th Annual Catalogue, 1910-1911. (Out of print.)
Vol. 2, No. 3, June, 1910. Some of the essentials of success, Charles Sumner Howe. (Commencement address, June 1st, 1910.)
Vol. 2, No. 4, Sept., 1910. Friction in small air pipes, E. G. Harris, Albert Park, H. K. Peterson. (Continued by Technical Series. Vol. 1, No. 1 and 4.)
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Vol. 3, No. 2, March 1st, 1911. 40th Annual Catalogue, 1911-1912.
Vol. 3, No. 3, June, 1911. Providing for future generations. E. R. Buckley. (Tau Beta Pi address, May 24th, 1911.)
Vol. 3, No. 4, Sept., 1911. Fall announcement of courses. (Out of print.)
Vol. 4, No. 1, Dec., 1911. Fortieth anniversary of the School of Mines and Metallurgy of the University of Missouri. Parker Hall Memorial address. Laying of cornerstone of Parker Hall, Rolla, Missouri, October 24th, 1911.
Vol. 4, No. 2, March, 1912. 41st Annual Catalogue, 1912-1913.
Vol. 4, No. 3, June, 1912. Mining and civilization. J. R. Finlay. (Commencement address, May 31st, 1912.)
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Vol. 5, No. 2, March, 1913. 42nd Annual Catalogue, 1912-1913.
Vol. 5, No. 3, Never published.
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Vol. 6, No. 1, Never published.
Vol. 6, No. 2, March, 1914. 43rd Annual Catalogue, 1913-1914.
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Vol. 7, No. 4, September, 1915. Register of graduates, 1874-1915.
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Vol. 8, No. 2, March, 1916. 45th Annual Catalogue, 1915-1916.
Vol. 8, No. 3, June, 1916. The Business of mining. W. R. Ingalls. (Commencement address, May 26, 1916.)
Vol. 8, No. 4, October, 1916. Register of graduates, 1874-1916.
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Vol. 9, No. 2, March, 1917. 46th Annual Catalogue, 1916-1917.
Vol. 9, No. 3, June, 1917. What should a present day metallurgical education comprise? C. H. Fulton. (Commencement address, May 25, 1917.)

Technical Series

Vol. 1, No. 1, November, 1911. Friction in air pipes. Technical Series. E. G. Harris, (Continuation of General Series, Vol. 2, No. 4.)
Vol. 1, No. 2, February, 1912. Metallurgy and ore dressing laboratories of the Missouri School of Mines and Metallurgy. D. Copeland, H. T. Mann, H. A. Roesler. (Out of print.)
Vol. 1, No. 3, May, 1912. Some apparatus and methods for demonstrating rock drilling and the loading of drill holes in tunneling. L. E. Young.
Vol. 1, No. 4, August, 1912. Friction in air pipes. E. G. Harris. (Continuation of Vol. 1, No. 1, November, 1911.)
Vol. 2, No. 1, August, 1916. Comparative tests of piston drill bits. C. R. Forbes and L. M. Cummings.
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Vol. 3, No. 3, February, 1917. A preliminary report on blended Portland cement. E. S. McCandliss.

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